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STIMULATED-EMISSION-OF-ENERGETIC-PARTICLES (SEEP) EXPERIMENT.(U)
SEP 79 N00014-78-C-0755
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MISSILES & SPACE COMPANY, INC. • SUNNYVALE, CALIFORNIA

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LMSC/D678462

Final rept. on phase 1,

FINAL REPORT
PHASE I
OF STIMULATED-EMISSION-OF-ENERGETIC-PARTICLES (SEEP) EXPERIMENT

~~Contract~~ N00014-78-C-0755

September 1979

Submitted to

R. G. Joiner
The Office of Naval Research
Arlington, Virginia 22217

by

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LOCKHEED PALO ALTO RESEARCH LABORATORY
LOCKHEED MISSILES & SPACE COMPANY, INC.
A SUBSIDIARY OF LOCKHEED AIRCRAFT CORPORATION

TABLE OF CONTENTS

1.0 SUMMARY OF WORK COMPLETED

A satellite payload has been conceived that will uniquely identify the magnitude and spatial extent of the particle precipitation induced by U.S. Navy operational VLF transmitters and the Stanford University experimental transmitter at Siple, Antarctica. A method has been conceived of modulating these transmitters in a manner that will permit unequivocal association of the observed precipitating particles with a given transmitter's operation. The planned SEEP experiment will have a sensitivity that is two to three orders of magnitude more sensitive than any previous experiment of this type.

The principal product of the planning phase of the SEEP experiment has been the completion of an updated DD form 1721 (Section 2.0 of this report) requesting flight for the SEEP experiment. This document describes the rationale for the experiment and summarizes the technical plans and requirements developed during the course of the Phase I contract. The 1721 was submitted to ONR on 6 April 1979 and was approved by U.S. Navy Rear Admiral Grover M. Yowell, on 14 June 1979.

Discussions concerning the SEEP experiment have been held with personnel of the USAF Space Test Program, the Office of Naval Research, and the spacecraft developer and program officer for a USAF program that could accomodate the SEEP flight hardware. An early resolution of whether this particular flight opportunity will materialize is expected. Alternate flight opportunities sponsored by the USAF Space Test Program have also been requested. The appropriate USN and USAF officials have been kept informed of these developments.

Conversations with Stanford University and the Naval Ocean Systems Center personnel have revealed no problems with implementing the transmitter keying required for the SEEP experiment.

Laboratory work to further develop the use of pulse-height analysis to improve the energy resolution of multi-channel charged particle analyzers has begun, as has work to improve the sensitivities of these detectors by using cooled-silicon detectors. This work has included initial breadboarding of detector circuits.

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Interface information for the satellite program mentioned above and the SEEP experiment has been exchanged and preliminary compatibility of requirements has been established.

In preparation for the SEEP program Lockheed Palo Alto Research Laboratory has added four persons to the professional staff.

The period of performance for this work began 1 October 1978. An extension of the ending date to 31 July 1979 has be requested. A follow-on proposal, (LMSC/D677016, May 1979), for the design and breadboarding phase of the SEEP experiment, has been submitted to the Office of Naval Research.

2.0 SPACE EXPERIMENTS SUPPORT PROGRAM FLIGHT REQUEST FOR SEEP (DD FORM 1721)

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SPACE EXPERIMENTS SUPPORT PROGRAM

I.	SESP SPACE FLIGHT REQUEST	
1. EXPERIMENT TITLE Stimulated Emission of Energetic Particle Experiment		2. SHORT TITLE SEEP
3. EXPERIMENT NO. ONR-804		4. COSATI NO. 1702, 1704, 2008
5. PROJECT NO. RR03208-01, 1-12	6. TASK NO. NR 089-142	7. PROGRAM ELEMENT NO. 61153N-32
8. SPONSOR Office of Naval Research, Mr. R. Gracen Joiner, Code 465		
9. MANAGEMENT OFFICE Office of Naval Research, Code 465, Arlington, VA 22217		
10. PROJECT OFFICE Navy Space Systems Activity, Code NSSA-40		

11. OBJECTIVE

The military objective of this experiment is to investigate the potential of controlled, transmitter-stimulated wave-particle interactions (SPI) in the magnetosphere as techniques for:

1) degrading/blacking out critical U.S. Navy communication and navigation links operating at HF, VLF and ELF through the selective precipitation of energetic electrons from the earth's radiation belts

2) jamming of VLF communications with ground-or-satellite-based VLF transmitter signals that are amplified in the magnetosphere

3) depleting the intense trapped radiation belts created by a high altitude nuclear burst

The immediate scientific objective of this stimulated-emission-of-energetic-particles (SEEP) program is to experimentally establish the detailed relationship between ground-based VLF transmitter activity (i.e. operating frequency, signal strength, pulse duration and duty cycle) and the characteristics of the resulting particle precipitation (intensity, energy and pitch angle distribution). Once these relationships are established an assessment can be made of the feasibility of using controlled wave-particle interactions as a selective method of precipitating electrons from the radiation belts onto critical communication links in the ionosphere. With this knowledge corrective actions to mitigate the effects of such activity against existing and planned U.S. Navy communication systems can be pursued. Correspondingly, possible applications of such a technique against comparable adversary communication and navigational systems, such as the Soviet ALPHA and BETA systems, can be considered.

12. JUSTIFICATION

Resonant interactions between waves and particles in the earth's magnetosphere can cause a violation of the adiabatic motion of the trapped electrons and protons in the radiation belts, Precipitation of these particles into the atmosphere/ionosphere induced by pitch angle diffusion associated with violation of the adiabatic motion is a major natural loss mechanism of geomagnetically trapped particles. Manifestations of such natural phenomena are the aurorae, relativistic electron precipitation events (REP), and post-storm precipitation events, all of which create anomalously high electron density levels in the ionosphere that result in disruptions of radio communication links operating at ELF (0.3 - 3 KHz), VLF (3 - 30 KHz) and HF (30 - 300 KHz). Details of the wave-particle interaction theory can be found in Kennel and Petschek (1966), Thorne (1975), Spjelkvik and Thorne (1975), Inan (1978) and Lyons and Williams (1978), and effects of the resulting particle precipitation on communication links can be found in Larsen et al. (1976), Larsen et al. (1977) and Imhof et al. (1978).

Existing critical U.S. Navy ionospheric communication links operating at HF, VLF and proposed links at ELF are susceptible to degradation from this energetic particle precipitation from the magnetosphere. This is illustrated in Figures 1 and 2.

Figure 1, taken from Larsen et al. (1977), shows the effect of a naturally-occurring electron precipitation event on the U.S. Navy VLF communication links monitored between the Applied Physics Laboratory (APL) near Washington, D.C. and transmitters in Rugby, United Kingdom (GBR) and Seattle, Washington (NLK). Phase advances of up to 10 microseconds over the normally undisturbed signals were measured at the time that the 1971-089A satellite was observing energetic electrons (>130 keV) precipitating into the communication path following the 17 December 1971 magnetic storm. These VLF links are sensitive to phase advances as small as 1 microsecond (Larsen et al., 1977) and hence this event presented a 10-fold disturbance increase.

Figure 2, taken from Imhof et al. (1978), shows that nighttime signal strengths received at Connecticut from an experimental U.S. Navy ELF transmitter operating in Wisconsin (WTF) at 75 Hz can be attenuated by as much as 5 db during the times that energetic electrons are precipitating into the transmission path near the receiver. This transmission system is an experimental prototype of the proposed SEAFARER worldwide communication link. Modeling of the morphology of the electron precipitation and its ionization effects within the transmission paths of the proposed system is in progress (Imhof et al., 1978). Mitigation techniques to overcome the signal strength loss due to enhanced ionization in the path, whether it occurs from natural precipitation, man-made transmitters or a high altitude nuclear detonation, are costly but must be considered in the design. The proposed SEEP experiment will provide a fundamental data base which will be used to influence these design parameters.

In recent years it has been recognized that ground-based electromagnetic sources can also influence both the wave and particle environment in the magnetosphere. Helliwell et al. (1975) were the first to show that harmonics of the line frequencies used in the North American power grid system exist in the magnetosphere and suggested that these waves might affect the radiation belt particles. Bullough et al. (1976) further suggested that the harmonics of the power lines in both North America and Europe could induce the precipitation of electrons from the mid-latitude slot region of the radiation belts. Park (1977) has also noted that power line radiation and the associated emissions can cause pitch angle scattering of electrons and may thereby exert a strong influence on the energetic particle population in the magnetosphere.

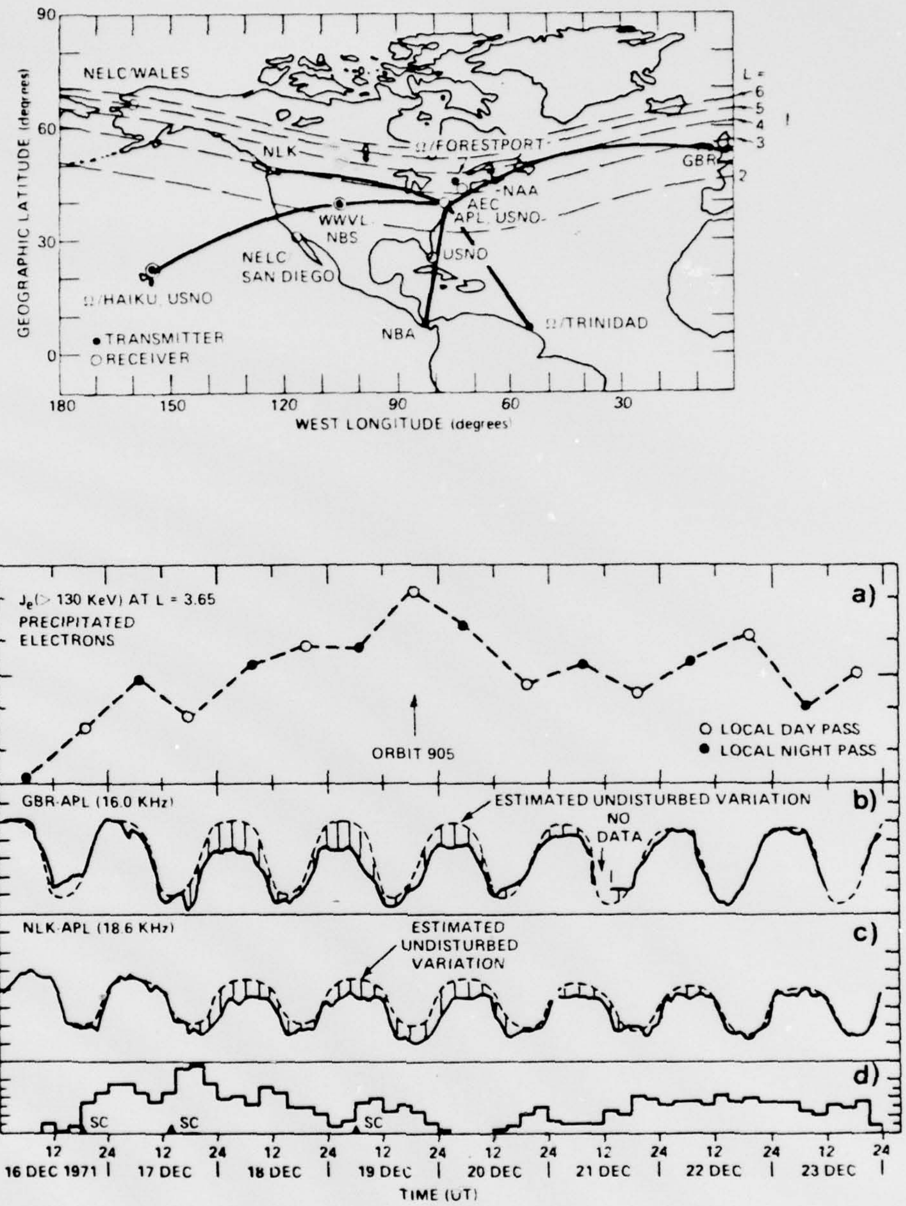
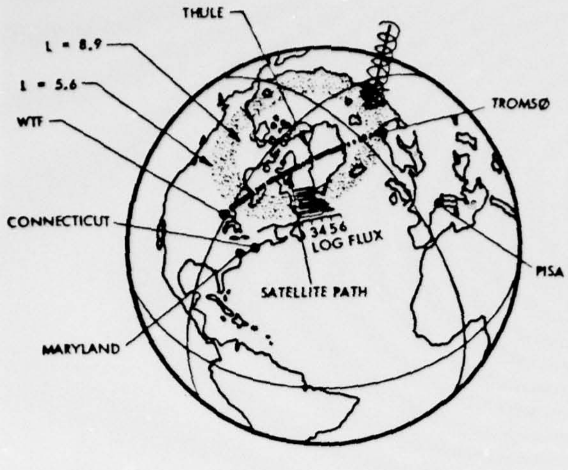
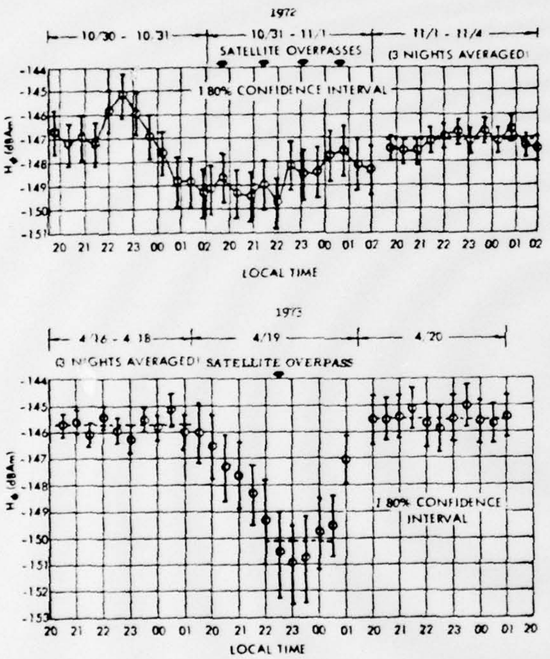


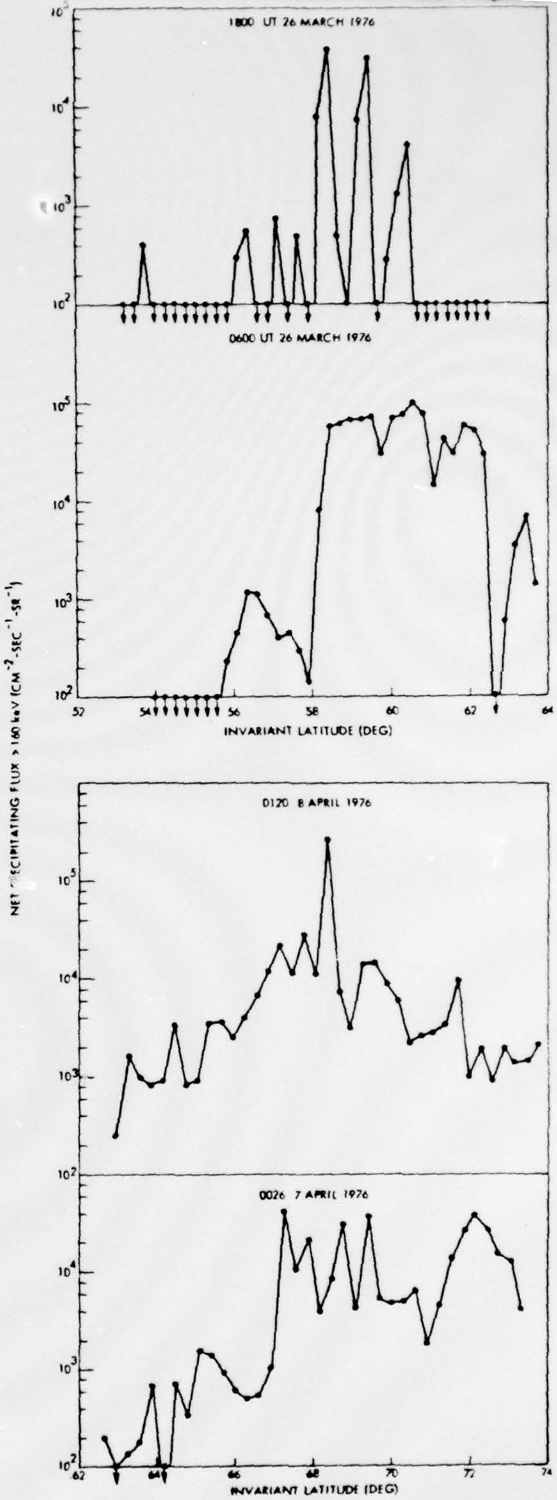
Figure 1. Correlation between phase anomalies observed on U.S. Navy VLF communication links operating between the United Kingdom (GBR), Seattle, Washington (NLK) and Washington, D.C. (APL) (top insert) during a time that energetic electrons were precipitating into the path. Taken from Larsen et al. (1977).



Schematic representation of the ELF propagation path from Wisconsin to Norway. Also shown is the path of the satellite through the outer radiation belt/auroral zone region. The measured fluxes of electrons above 160 keV are shown schematically for one of the coordinated passes.



The 76-Hz field strengths measured at the Connecticut receiving station versus time. Effective integration time: 32 min per sample [*Bannister et al.*, 1974; P. R. Bannister, personal communication, 1976].



Measured fluxes of precipitating electrons >160 keV plotted as a function of invariant latitude for selected passes during the coordinated exercise in March–April 1976.

Figure 2. Collection of data taken from Imhof et al. (1978) showing (top left) the ELF propagation path from the U.S. Navy WTF transmitter to Norway with respect to the natural energetic electron precipitation region and the fluxes measured in the path by a satellite during several coordinated events (right panel). Signal strength reductions of up to 5 db on the WTF-Connecticut link have been observed on occasions (lower left).

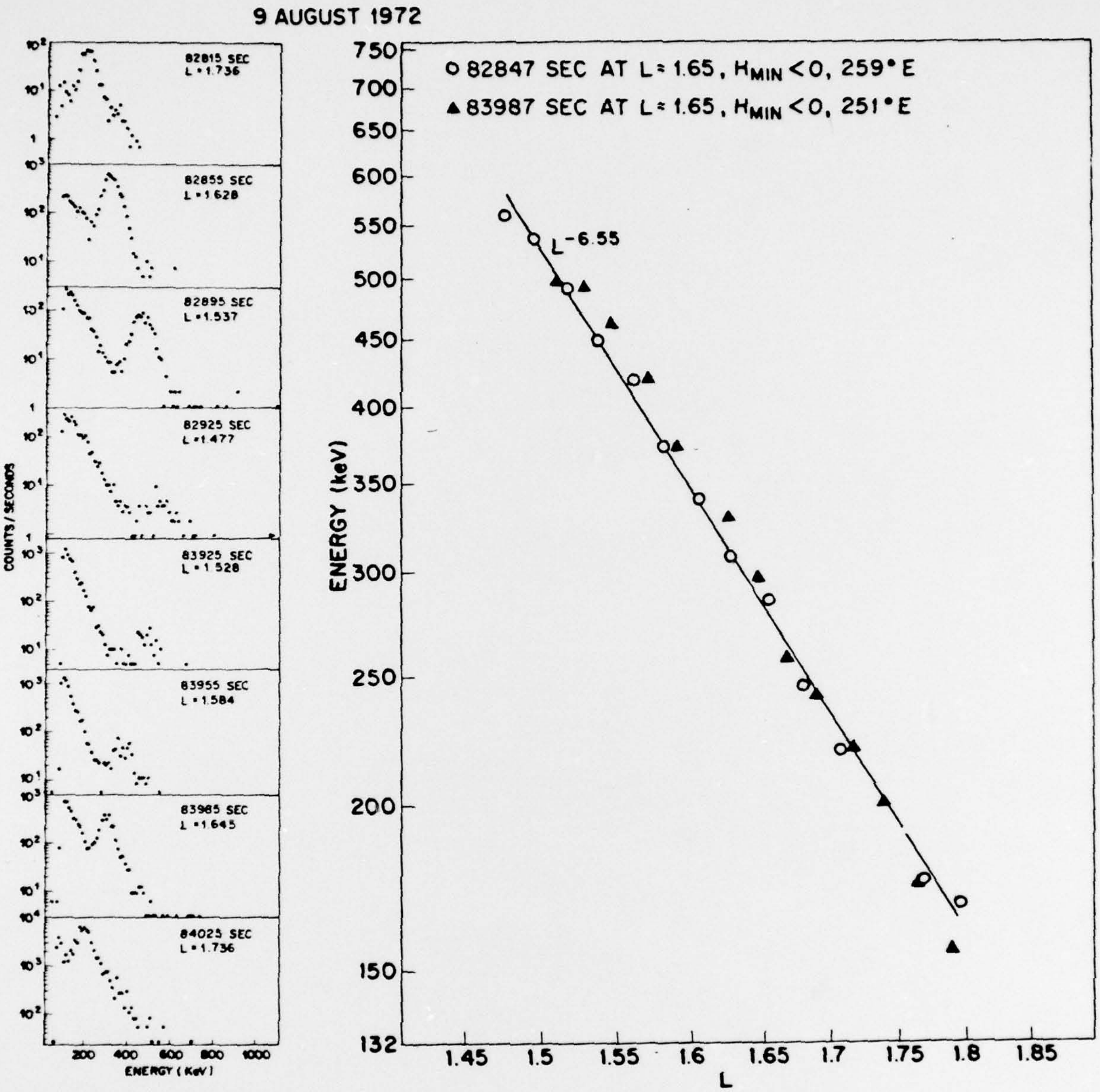


Figure 3. The central energy of the pronounced peaks observed by Imhof et al. (1974) in the precipitating electron flux (left panel) when plotted against the L-shell of observation (right panel) show a well behaved relationship consistent with a simple WPI involving these electrons and monofrequency VLF waves.

Imhof et al. (1974) suggested that radiation from ground-based transmitters such as those employed by the U.S. Navy for critical communications may be responsible for the L-dependent peaks observed in the energy spectra of precipitating electrons shown in Figure 3. The pronounced energy peaks vary with magnetic L-shell in a manner that is completely consistent with a simple gyro-resonant interaction of these electrons in the equatorial region with monofrequency waves near 10 KHz. Vampola and Kuck (1978) have recently claimed a relationship between electron precipitation and the operation of VLF transmitters, particularly of the USSR transmitter coded UMS located at 44°E, 46.2°N. The Soviets operate a three station high-power VLF communication system and a one station VLF navigational timing system for similar purposes to the U.S. Navy. Heating of ionospheric electrons with high power transmitters is another form of wave-particle experimentation that is being heavily conducted in the Soviet Union (Getmantsev et al., 1974; Vaskov and Gurevich, 1975; and Mityakov et al., 1976).

Active VLF wave injection experiments to study wave-particle interactions have been carried out by the Stanford group at Siple station in Antarctica for several years now. Coherent whistler-mode signals injected into the magnetosphere in the 1.5 to 16 KHz range from the transmitter at Siple, Antarctica (76°S latitude, 80°W longitude, L = 4.1) have been observed at the Siple conjugate point near Roberval, Canada (48°N latitude, 73°W longitude). The signals followed field-aligned ducts near L = 4 and generally showed exponential growth as a function of time, with growth rates of the order of 128 db/second and total power gains of up to three orders of magnitude having been observed, as shown in Figure 4 taken from Helliwell and Katsufrakis (1974). Inan et al. (1978) have developed a theoretical model of the coherent interaction of monofrequency waves, such as from a transmitter, with a trapped particle distribution.

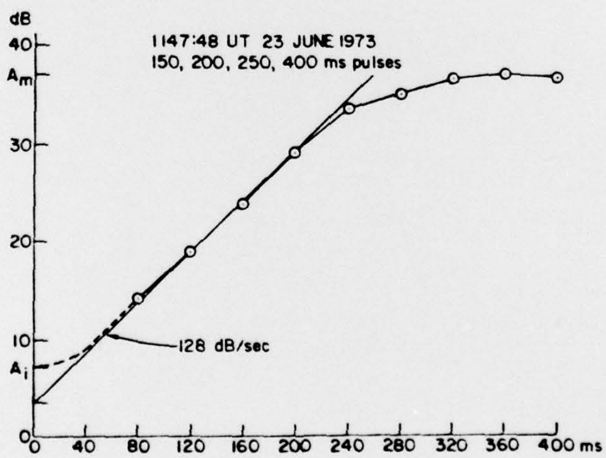


Figure 4. Average amplitudes of the output pulses as a function of time after the start of the received pulse at the Stanford station in Canada. The transmitter source of the pulses was at Siple, Antarctica. The straight line fit gives an exponential growth rate of 128 db/sec and the total wave amplification was 30 db.

The model can predict the flux of precipitating particles expected on a given field line given the particle distribution function and the wave intensity and frequency in the equatorial region.

While there has been much experimentation and data on waves and particles obtained independently, there have been no planned, coordinated experiments to date which uniquely correlate the characteristics of a transmitter-generated wave environment (frequency, duty cycle, pulse duration, power etc.) with the characteristics of the precipitated electrons (intensity, energy and pitch angle distribution). Before further advances can be made in this field these fundamental data must be obtained. A prime objective of the SEEP experiment is to obtain these cause-and-effect relationships.

Because it has been demonstrated that coherent VLF waves from a ground-based transmitter can at times derive energy from the electrons in a WPI and be amplified up to 30 db in the magnetosphere (Helliwell and Katsufrakis, 1974), the feasibility of this technique to noise jam vital VLF communication links must be assessed. An understanding of the magnetospheric conditions (wave, plasma and particle distributions) under which such amplifications occur is essential to advancement in this area.

Finally, an intense long-lived energetic electron belt follows the detonation of a high altitude nuclear burst at mid- and low latitudes. As an example, the U.S. high-altitude nuclear test, Starfish, conducted in 1962 resulted initially in a radiation belt intense enough to degrade and destroy a few satellites and created a high radiation background for subsequent satellite missions until 1965. The potential advantages of utilizing transmitted-induced WPI to selectively precipitate the trapped fission electron from an artificial radiation belt on a time scale faster than the few year natural decay rate are obvious. The feasibility of achieving these rapid decay rates can only be assessed when the experimental data base, such as proposed in this experiment, relating the waves and the particles is acquired.

REFERENCES

1. Amon L.E.S., and R.L. Dowden, VLF Stations Detected at Dunedin, University of Otago, New Zealand report, Feb 1977.

2. Bullough, K., A.R.L. Tatnall, and M. Denby, Man-made ELF/VLF emissions and the radiation belts, Nature, 260, 401, 1976.

3. Helliwell, R.A., and J.P. Katsufrakis, VLF wave injection into the magnetosphere from Siple Station, Antarctica, J. Geophys. Res., 79, 2511, 1974.

4. Helliwell, R.A., J.P. Katsufrakis, T.F. Bell, and R. Raghuram, VLF line radiation in the earth's magnetosphere and its association with power system radiation, J. Geophys. Res., 80, 4249, 1975.

5. Imhof, W.L., E.E. Gaines, and J.B. Reagan, Evidence for the resonance precipitation of energetic electrons from the slot region of the radiation belts, J. Geophys. Res., 79, 3141, 1974.

6. Imhof, W.L., J.B. Reagan, E.E. Gaines, T.R. Larsen, J.R. Davis, and W. Moler, Coordinated measurements of ELF transmission anomalies and the precipitation of energetic particles into the ionosphere, Radio Science, 13, 717, 1978.

7. Inan, U.S., T.F. Bell, and R.A. Helliwell, Nonlinear pitch angle scattering of energetic electrons by coherent VLF waves in the magnetosphere, J. Geophys. Res., 83, 3235, 1978.

8. Kennel, C.F., and H.E. Petschek, Limit on stably trapped particles, J. Geophys. Res., 71, 1, 1966.

9. Larsen, T.R., W.L. Imhof and J.B. Reagan, L-Dependent Energetic Electron Precipitation and Mid-Latitude D Region Ion Pair Production Profiles, J. Geophys. Res, 81, 3444, 1976.

10. Larsen, T.R., T.A. Potemra, W.L. Imhof and J.B. Reagan, "Energetic Electron Precipitation and VLF Phase Disturbance at Middle Latitudes Following the Magnetic Storm of December 16, 1971, J. Geophys, Res, 82, 1579, 1977.

11. Lyons, L.R., and D.J. Williams, A comment on the effects of man-made VLF waves on the radiation belts, Geophys. Res. Letters, 5. 116-118, 1978.

12. Park, C.G., VLF wave activity during a magnetic storm: a case study of the role of power line radiation, J. Geophys, Res., 82, 3251, 1977.

13. Spjelkvik, W.N. and R.M. Thorne, A Simplified D-region model and its application to magnetic storm after effects, J. Atmos. Terr. Phys. 37, 777, 1975.

14. Thorne, R.M., Ionosphere-Magnetosphere Coupling 3. Role of Wave-Particle Interactions, Rev. Geophys. and Space Phys., 13, 878, 1975.

15. Vaskov, V.V., and A.V. Gurevich, Nonlinear resonant instability of a plasma in the field of an ordinary electromagnetic wave, Sov. Phys. JETP, Engl. Transl., 42, 91, 1975.

13. HISTORY

The experimental data base acquired to date on transmitter-induced particle precipitation was outlined in the previous section. While there have been independent wave and particle measurements performed in the past involving both natural and transmitter-induced activity, there have been no coordinated, planned experiments reported in which a unique cause-and-effect relationship could be demonstrated between a given transmitter operation and a corresponding signature in particle precipitation. This situation exists partially from the limited number of controlled transmitter experiments performed to date and partially from the lack of particle measurements made with sufficient sensitivity and temporal resolution on appropriate satellite platforms. The SEEP experiment will overcome both of these previous limitations.

14. IMPACT OF NO SPACEFLIGHT

The satellite portion of the experiment is essential to obtaining definitive measurements of the effects of the transmitted waves on the trapped particle population in the magnetosphere. Without the satellite experiment, the detailed physics of the cause-and-effect relationship cannot be established. Without the detailed physics knowledge, assessment of the impact of this phenomena on existing U.S. Navy communication systems operating at VLF (TACAMO) and on proposed systems at ELF (SEAFARER) cannot be made. Without this fundamental data base we cannot extrapolate to the effects that higher power transmitters, different operating frequencies and different magnetospheric conditions may have on these communication systems.

15. FUTURE PLANS

Subsequent satellite flights operated in other regions of the magnetosphere in conjunction with higher power transmitters will be required to assess the full potential of this phenomena as a communication-jamming technique and as a method of depleting artificial radiation belts. For example, the proposed Plasma Interaction Experiment (PIE-II-ONR-805) will explore the microscopic physics of the wave-particle-interaction phenomena in the source region which is thought to be near the equator on a magnetic field line. Future experiments, such as CRLS 252, also involve the operation of a VLF transmitter onboard a satellite to stimulate the wave-particle-interactions. The SEEP experiment will provide the fundamental causal (wave frequency, intensity, pulse rate, etc.) and effect (particle intensity, energy spectra, spatial location) information necessary to plan these most sophisticated, microscopic experiments of the future. SEEP is a modest, initial effort utilizing existing ground-based transmitters in an attempt to obtain a fundamental data base in a timely manner.

18. DESCRIPTION

The SEEP experiment involves the coordinated activities of controlled transmission of VLF waves into the magnetosphere from existing operational and experimental ground-based transmitters and the simultaneous observation of precipitating electrons with a satellite payload. The experiment concept is illustrated in Figure 5.

Modulated VLF waves from existing US Navy operational transmitters such as NAA in Cutler, Maine, NSS in Washington, D.C., NLK in Seattle, Washington, from transmitters in the OMEGA navigational timing network and from the Stanford University experimental transmitter at Siple, Antarctica, will be injected into the magnetosphere at the times that the proposed polar orbiting satellite is crossing the foot of the magnetic shells excited by the waves. Reception of the NAA, NSS, NLK and OMEGA signals will be at the Siple station. Reception of the Siple transmissions will be at the conjugate station in Roberval, Canada. Instruments in the satellite payload will be oriented to monitor the precipitating electron fluxes flowing along the magnetic field, the trapped particle population perpendicular to the field and the atmosphere below where the particles interact and create bremsstrahlung photons that can be observed at the satellite.

A key element in the experiment is the controlled transmitter operations. Unique on-off patterns of transmissions will be employed such that the satellite payload can unequivocally associate the precipitating electrons with a given transmission site. This is an element that has been missing in previous experimental attempts to assess the effects of man-made waves on the precipitated particles. In a recent report (Amon and Dowden, 1977) the number of VLF stations around the world whose signals can be detected at Dunedin, New Zealand is 65, including 23 in the Soviet Union. The large number of these transmitters operating in an uncontrolled manner makes the unique identification of particle precipitation effects difficult. It may well be at the present time that a significant fraction of the electron precipitation into the ionosphere at mid-latitudes is initiated by these collective transmitter operations. This identification difficulty will be overcome in the SEEP experiment in that U.S. Navy operational transmitters and the Stanford University Siple transmitter will be operated in a controlled transmission mode at the time of the satellite overpasses. The Navy personnel responsible for the operational transmitters have been approached and have agreed to cooperate in the SEEP experiment. The controlled transmission experiment will be repeated for several months so that a data base on the precipitated particle population can be obtained in conjunction with different operating duty cycles and magnetospheric conditions.

The second key element in the experiment is the unique capability of the proposed satellite orbit and the payload. A low-altitude polar orbit utilizing an existing host vehicle satellite is proposed. The polar-orbit allows overpass coverage of all of the exisiting VLF transmitters in the world and their magnetic field line intercepts every day, including the Siple station in Antarctica. A lower inclination orbit, such as from the STS, would reduce the number of cooperative transmitters that could be used and the short 7-day duration of the STS flights would significantly reduce the data base obtained unless multiple missions were flown. The low altitude of the proposed satellite orbit (<300 km) has a unique advantage in that the trapped background radiation is greatly reduced and much higher particle detection sensitivity can be obtained.

LOCKHEED

STIMULATED EMISSION OF ENERGETIC PARTICLES (SEEP) EXPERIMENT

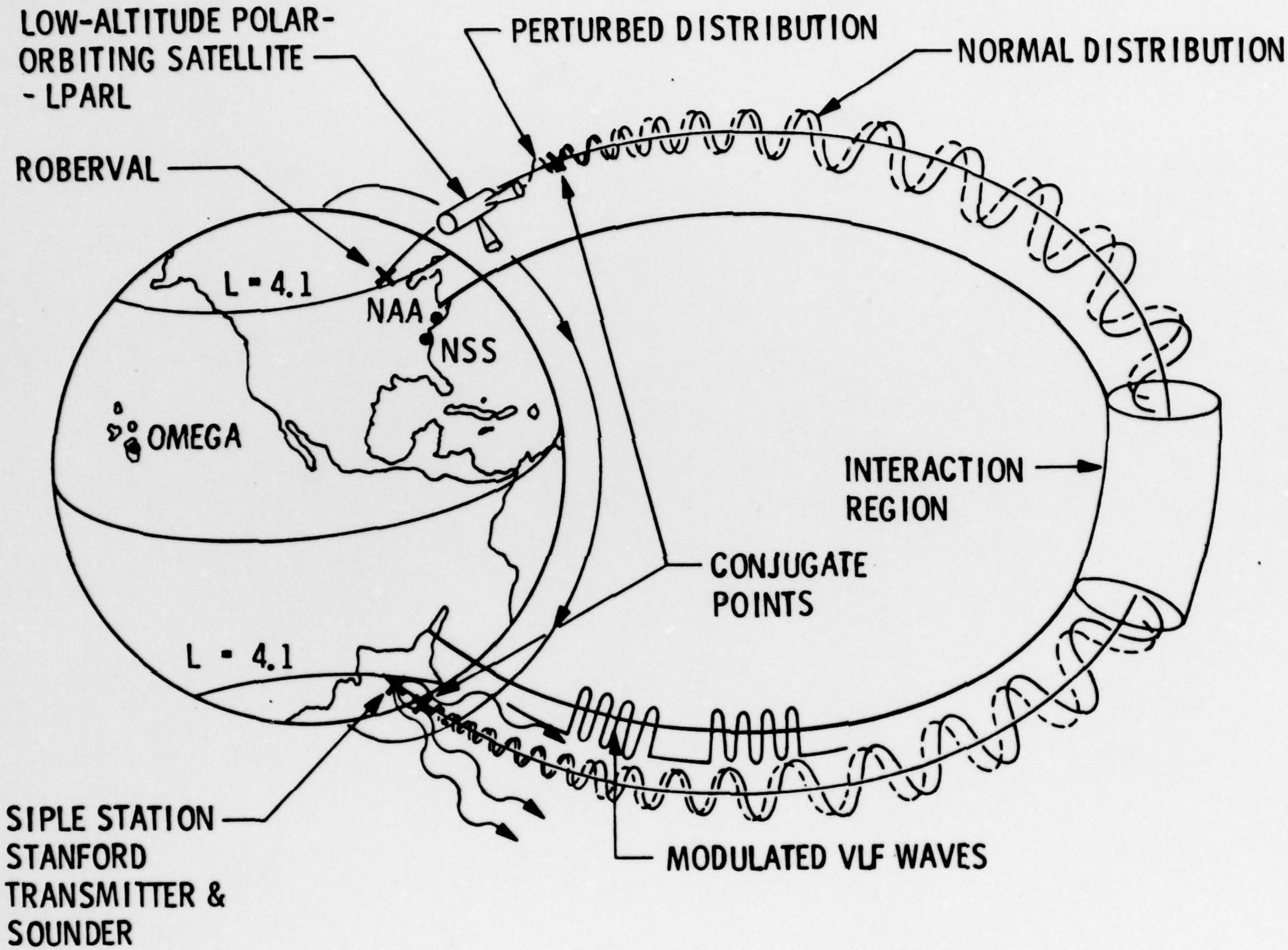


FIGURE 5. SCHEMATIC REPRESENTATION OF THE SEEP EXPERIMENT

16. DESCRIPTION (Cont'd)

The particle detectors in the SEEP payload will have at least a factor of 100 more detection sensitivity than instrumentation used in previous experiments. This high sensitivity, which will be achieved with thermoelectric-cooled silicon detectors, will provide positive identification of the bursts of precipitating electrons in the loss cone expected in association with the pulsed transmitter operation. Two spectrometers designated as LEEPS and MEEPS, for Low-Energy Electron Precipitation Spectrometer and Medium Energy Electron Precipitation Spectrometer respectively, will be oriented on the stabilized spacecraft to view along the zenith to detect the precipitating electrons in the bounce loss cone. The TEES (Trapped Energetic Electron Spectrometer) instrument will view perpendicular to the zenith to monitor the trapped and drift loss cone particle population.

A unique feature of the payload that will greatly enhance the overall detection capability is the imaging of the precipitating electrons over a spatial scale much larger than the direct satellite sampling. This will be accomplished with an x-ray imaging spectrometer (XRIS) that views the nadir and spatially images the bremsstrahlung photons created when the precipitated electrons slow down and stop in the atmosphere. The high temporal and energy resolution capabilities of the XRIS will permit the unique discrimination of the transmitter-induced electrons from the general precipitation background. With this technique the beams of electrons excited by the transmitters can be detected over several hundred kilometers in area even though the satellite may not be sampling the direct beam on a given orbit.

The orientation of the SEEP payload on a stabilized satellite is shown in Figure 6. The electron spectrometers would be located as described above and perpendicular to the satellite velocity-vector. The XRIS has a $\pm 20^{\circ}$ field-of-view (FOV) in the plane of the velocity vector and $\pm 30^{\circ}$ FOV perpendicular to that plane.

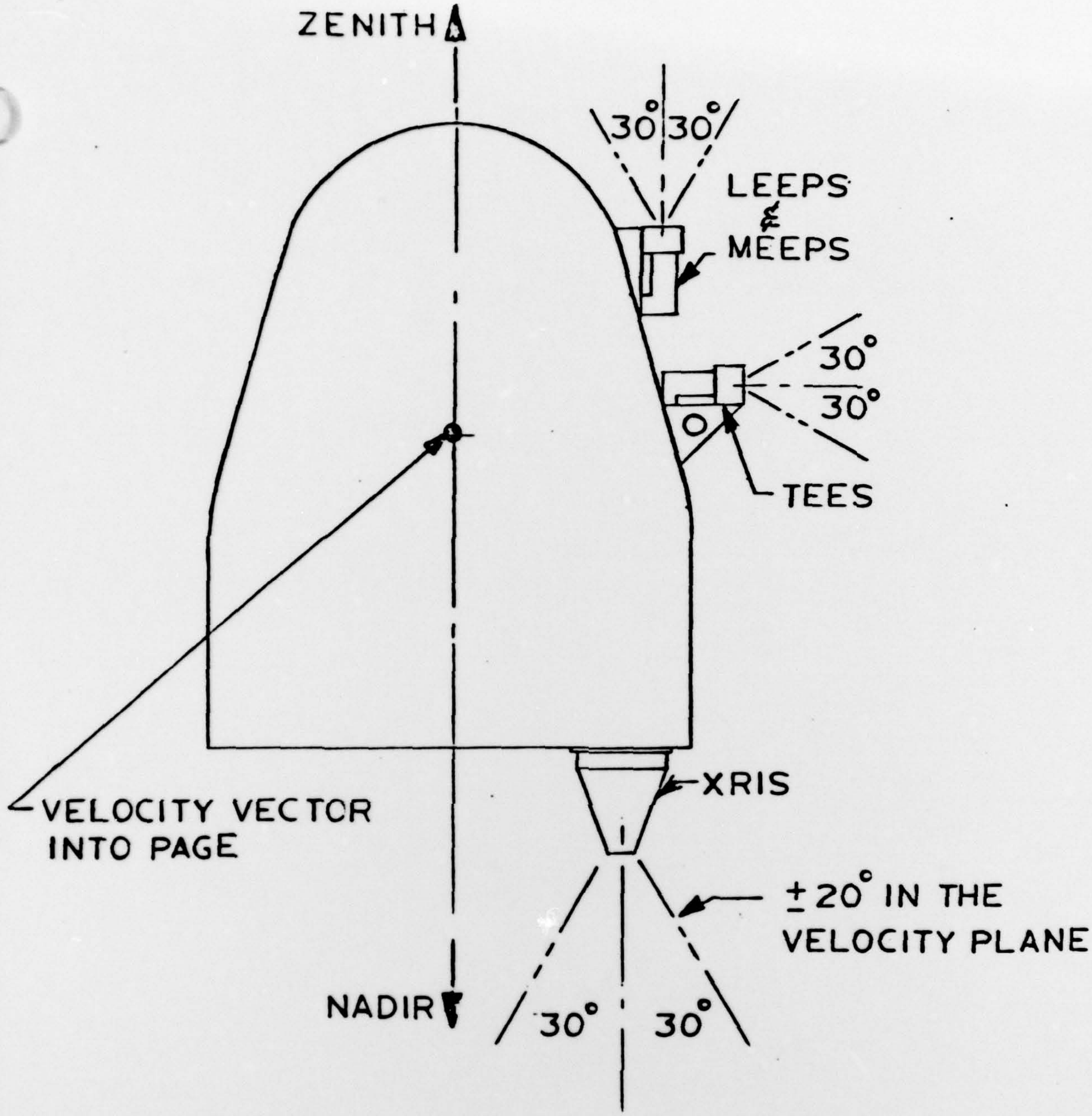


FIGURE 6

SEEP ORIENTATION

APR 79 LA HOOKER

LOCKHEED MISSILES & SPACE COMPANY, INC. A SUBSIDIARY OF LOCKHEED AIRCRAFT CORPORATION SUNNYVALE, CALIFORNIA	SIZE A	CODE IDENT NO. 17077	DWG NO. 10001	REV
	SCALE NO		SHEET 1	

FORM LMSC 8050 G-1

II. TECHNICAL DETAILS

17. ☐ MANNED ☒ UNMANNED

18. ☐ SPACECRAFT WITH MOTOR ☐ SPACECRAFT ☒ EXPERIMENT ONLY

19. WEIGHT	20. VOLUME	21. AVG. POWER	22. PEAK POWER	23. AVG. WATT-HR/ORBIT	24. DUTY CYCLE
41b(24.5KG)	$0.051M^3$	19W	20W	15	50%

25. ORBITAL LIFE
MIN 6 months ± 3 months MAX 2 years ± 6 months

26. INCLINATION
90° + 20° − 20°

27. ORBIT
APOGEE 150NM + 50 − 50 PERIGEE 150NM + 50 − 50

28. LAUNCH DATE
EARLIEST 1981 LATEST 1982

29. RECOVERY
☐ YES ☒ NO

30. LAUNCH WINDOW
NO REQUIREMENT

31. ATTITUDE Earth-Center Oriented; Zenith and Nadir Viewing Required

32. STABILIZATION
THREE-AXIS STABILIZED

33. STABILIZATION ACCURACY
X-AXIS ± 1° Y-AXIS ± 1° Z-AXIS ± 1°

34. STATION KEEPING
ONLY AS NECESSARY TO MAINTAIN STABILIZATION

35. SPECIAL REQUIREMENTS
A MAGNETIC TAPE RECORDER OR OTHER STORAGE DEVICE CAPABLE OF RECORDING A FEW ORBITS OF DATA AT A 32 KBPS RATE IS REQUIRED.

36. RADIATING DEVICES ☐ NUCLEAR POWER ☐ RADIOSOTOPES ☐ RADIOACTIVE HEAT SOURCE ☒ RADIOACTIVE CALIBRATOR ☐ OTHER

EXPLANATION:
WEAK ALPHA-EMITTING RADIOACTIVE SOURCES (<1 MICROCURIE) WILL BE ENCLOSED IN EACH INSTRUMENT FOR CALIBRATION PURPOSES

37. TELEMETRY REQUIREMENTS

THE EXPERIMENT CONTAINS A DIGITAL DATA HANDLING UNIT (IDHU) THAT COLLECTS AND CONTROLS INFORMATION FROM THE INSTRUMENTS AND PROVIDES A SGLS-COMPATIBLE SERIAL PCM (B1-Ø-L, OR NRZ) OUTPUT TO TELEMETRY AT 32.0 KBPS. THE IDHU IS SIMILAR TO UNITS SUCCESSFULLY FLOWN ON THE P71-2, P72-1 AND P78-1 SPACECRAFT.

38. TRACKING EPHEMERIS
☐ INITIAL ORBIT ☐ PERIODIC UPDATES ☒ MISSION LIFETIME

39. COMMAND CONTROL (*Quantity of Functions*)
10 DISCRETE, 1 MAGNITUDE

40. DATA COLLECTORS

NAME	PARAMETER	DIMENSIONS	WEIGHT	VOLUME
1. TRAPPED ENERGETIC ELECTRON SPECTROMETER (TEES)	ELECTRONS 30-2000 keV	15.2x15.2cm x 27.9cm	9 LB	.0065M^3
2. LOW ENERGY ELECTRON PRECIPITATION SPECTROMETER(LEEPS)	ELECTRONS 1-50 keV	15.2x15.2cm x 27.9cm	9 LB	.0065M^3
3. MEDIUM ENERGY ELECTRON PRECIPITATION SPECTROMETER (MEEPS)	ELECTRONS 30-1000 keV	15.2x15.2cm x 27.9cm	9 LB	.0065M^3
4. X-RAY IMAGING SPECTROMETER (XRIS)	X-RAYS 1-100 keV	35.6x22.9cm x35.6cm	15 LB	.029M^3
5. INTERFACE AND DATA HANDLING UNIT (IDHU)	DATA HANDLER	8.9x14.0cm x 21cm	6 LB	.0026M^3
6. CABLE HARNESS		AS REQUIRED	6 LB(EST)	
TOTAL			54LB (24.5 KG)	.051M^3

41. SPACE CRAFT STOWED DIMENSIONS

SEE ATTACHED DRAWING 10001

42. STATUS OF DESIGN DRAWINGS AND SPECIFICATIONS

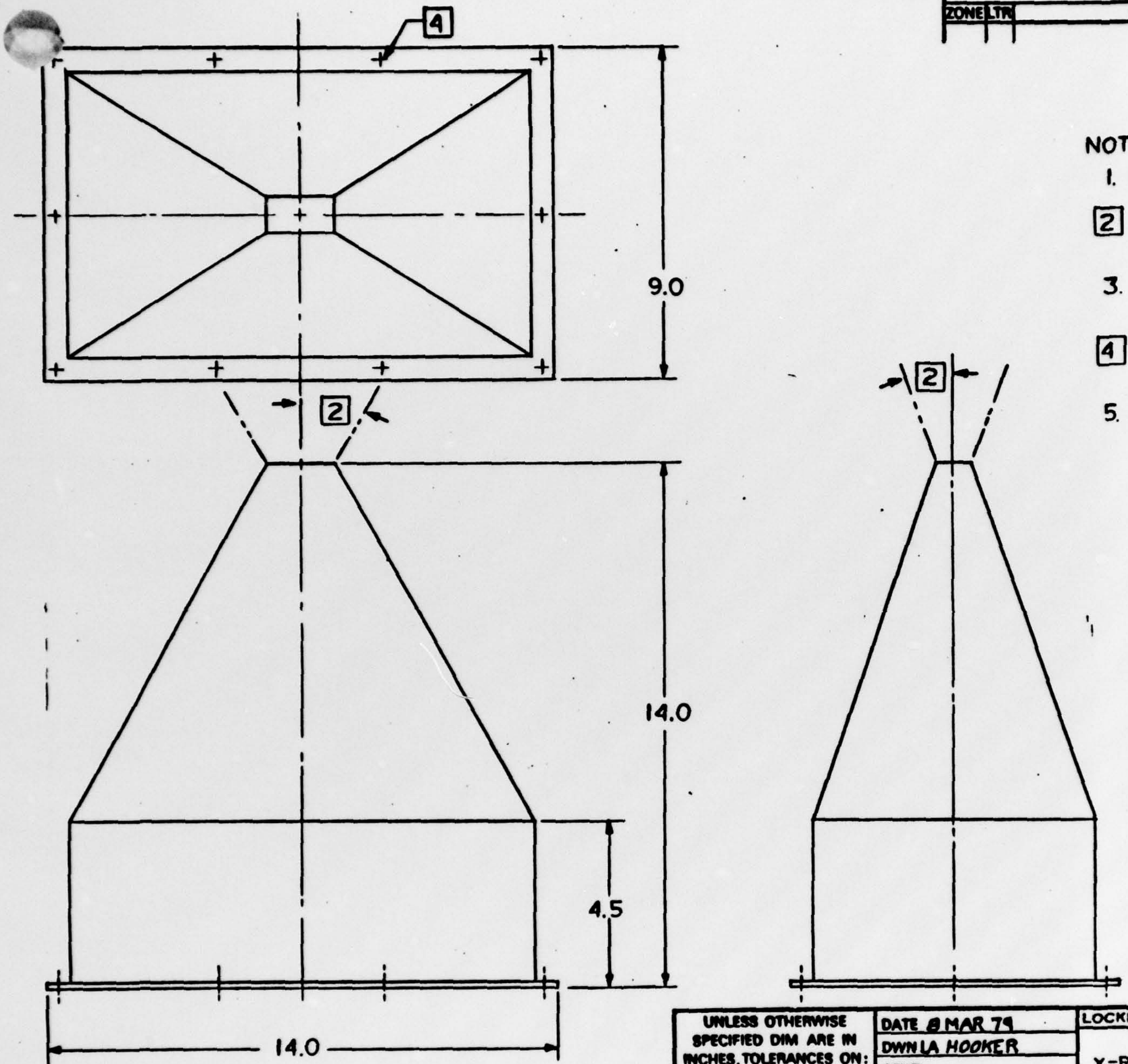
SEE ATTACHED DRAWING 1932, 1933, 1934

43. ENVIRONMENTAL DATA

- DESIRED OPERATING TEMPERATURE RANGE -10^{o}C to +0^{o}C
- INSTRUMENTS WILL MEET THE EMI REQUIREMENTS OF MIL STD 461A AND 1541

44. ASTRONAUT PARTICIPATION

NONE



NOTES:

1. REFERENCE DRAWING
2. [2] ± 30 X ± 20 DEGREES FIELD OF VIEW
3. CONNECTOR LOCATION TO BE DETERMINED
4. [4] PROPOSED MOUNTING LOCATION (10) PLC.
5. ESTIMATED WEIGHT 15 LBS.

REVISIONS				
ZONE	LTR	DESCRIPTION	DATE	APPD

UNLESS OTHERWISE SPECIFIED DIM ARE IN INCHES. TOLERANCES ON: FRACTIONS = ± 1/16 DECIMALS: .X = ± .1 .XX = ± .03 .XXX = ± .010 ANGLES = ± 2 DEG	DATE 8 MAR 74	LOCKHEED MISSILES & SPACE COMPANY, INC
	DWN LA HOOKER	S.E.E.P. X-RAY IMAGING SPECTROMETER (XRIS)
	APVD	
	APVD	
	ENGRG	SIZE C · CODE IDENT 17077 · DRAWING NO. 1932 · REV –
	CHKR	SCALE 1/2 · SHEET 1 OF 1

FORM LMSC 9051CC PRINTED ON LMSC CODE D

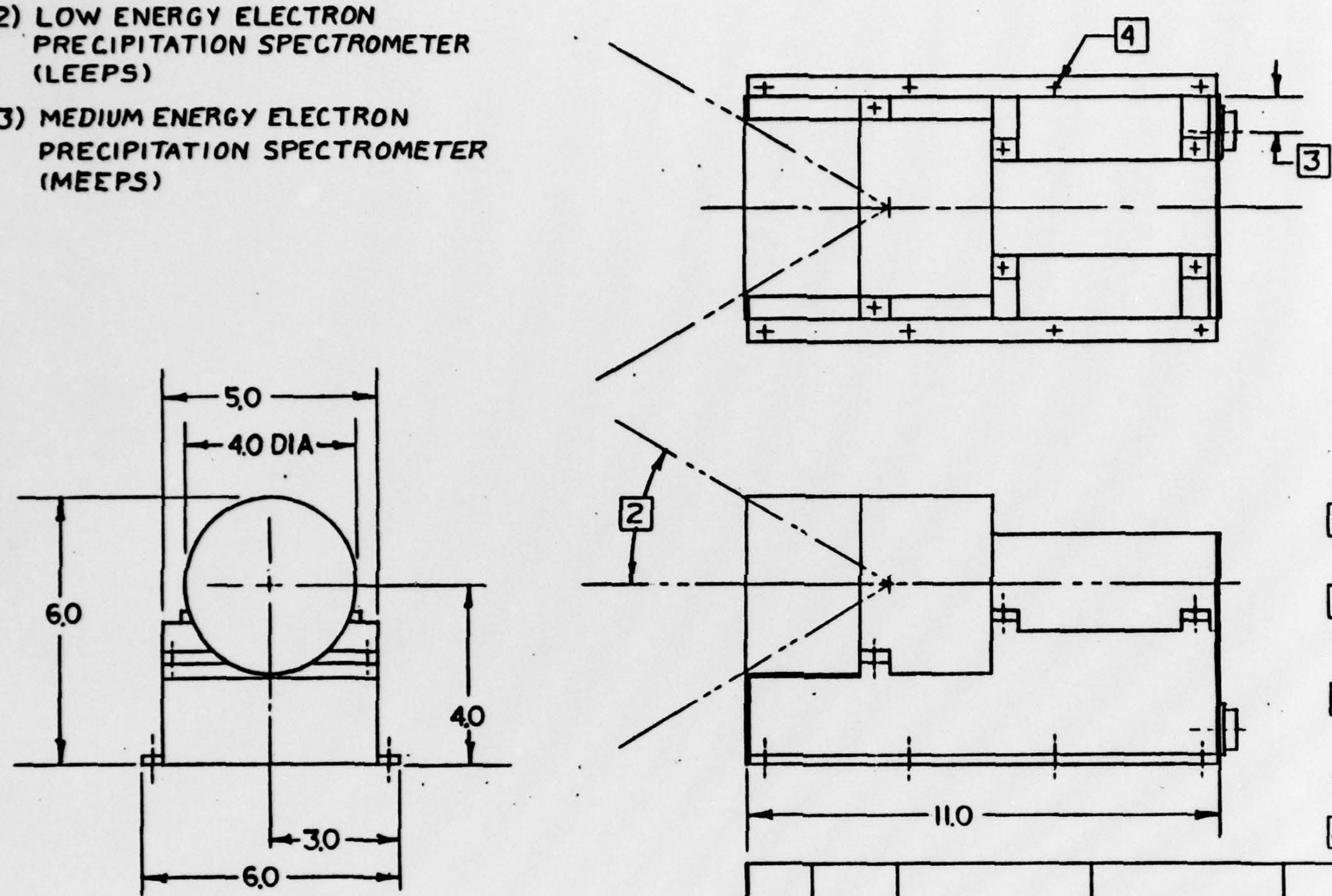
REVISIONS				
ZONE	LTR	DESCRIPTION	DATE	APVD

6 SPEC[illegible]METER OUTLINE IS REP[illegible]NTATIVE OF

(1) TRAPPED ENERGETIC ELECTRON SPECTROMETER (TEES)

(2) LOW ENERGY ELECTRON PRECIPITATION SPECTROMETER (LEEPS)

(3) MEDIUM ENERGY ELECTRON PRECIPITATION SPECTROMETER (MEEPS)



NOTES:

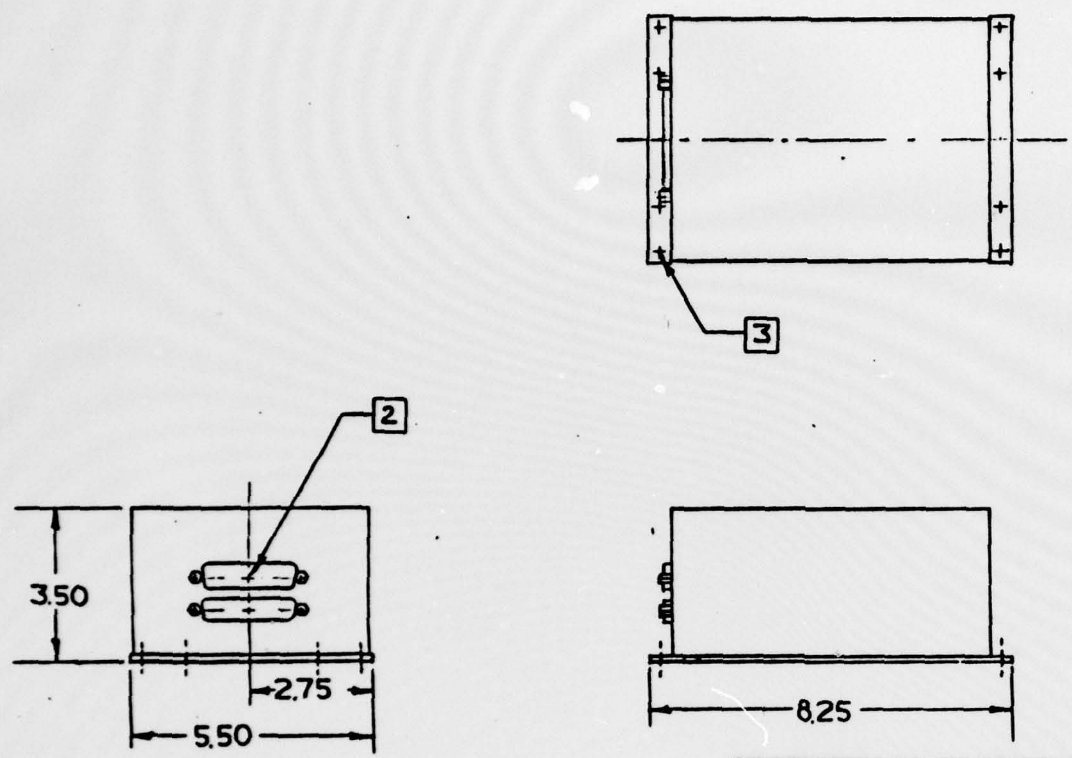
1. REFERENCE DRAWING
2. ± 30 DEGREE FIELD OF VIEW CONE
3. PROPOSED LOCATION OF CONNECTOR SUBJECT TO CHANGE
4. PROPOSED MOUNTING LOCATION (8) PLC.
5. ESTIMATED WEIGHT 9 LBS. EACH
6. SPECTROMETERS

QTY REQD	CODE IDENT	PART OR IDENTIFYING NO	NOMENCLATURE OR DESCRIPTION	MATERIAL DESCRIPTION OR NOTE	MATERIAL SPECIFICATION	ZONE	ITEM NO

PARTS LIST

INTERPRET DWG PER	UNLESS OTHERWISE SPECIFIED DIM ARE IN INCHES. TOLERANCES ON: FRACTIONS = ± 1/16 DECIMALS: .X = ± .1 .XX = ± .03 .XXX = ± .010 ANGLES = ± 2 DEG	DATE 28 FEB 79	LOCKHEED MISSILES & SPACE COMPANY, INC SUNNYVALE, CALIFORNIA
		DWN LA HOOKER	S.E.E.P. ENERGETIC ELECTRON SPECTROMETERS (TEES) (LEEPS) (MEEPS)
		APVD	
		APVD	
		ENGRG	
		CHKR	
NEXT ASSY / USED ON	CONTR	APVD	SIZE C · CODE IDENT 17077 · DRAWING NO 1933 · REV
APPLICATION	CCA/CI/FD	APVD	SCALE 1/2 · SHEET 1 OF 1

REVISIONS				
ZONE	LTR	DESCRIPTION	DATE	APVD



NOTES:

1. REFERENCE DRAWING

[2] PROPOSED LOCATION OF CONNECTOR SUBJECT TO CHANGE

[3] PROPOSED MOUNTING LOCATION (8) PLC.

4. ESTIMATED WEIGHT 6 LBS.

QTY REQD	CODE IDENT	PART OR IDENTIFYING NO	NOMENCLATURE OR DESCRIPTION	MATERIAL DESCRIPTION OR NOTE	MATERIAL SPECIFICATION	ZONE	ITEM NO

PARTS LIST

INTERPRET DWG PER	
NEXT ASSY	USED ON
APPLICATION	

UNLESS OTHERWISE SPECIFIED DIM ARE IN INCHES. TOLERANCES ON:
FRACTIONS = ± 1/16
DECIMALS: .X = ± .1
.XX = ± .03
.XXX = ± .010
ANGLES = ± 2 DEG

CONTR

CCA/CI/FD

DATE	28 FEB 79
DWN	LA HOOKER
APVD	
APVD	
ENGRG	
CHKR	
APVD	
APVD	

LOCKHEED MISSILES & SPACE COMPANY, INC
SUNNYVALE, CALIFORNIA

S.E.E.P.
INTERFACE & DATA HANDLING UNIT (IDHU)

SIZE	CODE IDENT	DRAWING NO	REV
C	17077	1934	-
SCALE 1/2		SHEET 1 OF 1	

III. PROGRAM INFORMATION			
45. STATUS ☐ UNFUNDED ☒ FUNDED ☐ BREADBOARD ☒ UNDER CONSTRUCTION ☐ AVAILABLE			
46. DESIGN FREEZE DATE FALL 1979		47. DELIVERY DATE SPRING 1981	
48. TOTAL COST 1200K	49. PRIOR FY FUNDS NONE	50. CURRENT FY FUNDS A 100K	51. FUTURE FY FUNDS 1100K
52. BUDGET/PROGRAM AUTH NO.			
53. CONTRACTOR LOCKHEED PALO ALTO RESEARCH LABORATORY		54. LOCATION OF CONTRACTOR WORK PALO ALTO, CALIFORNIA	
55. CONTRACT NO. N00014-78-C-0755		56. PLANNED CONTRACT OBLIGATION DATE Contract in force	

57. COORDINATION SUMMARY

1. U.S. Navy Space Experiments Committee Review, August 1977, held at Naval Research Laboratory, Washington, D.C. -- SEEP Experiment reviewed for objectives, approach and relevance to Navy needs. Experiment received Category 1 rating because of importance and relevance to Navy HF, VLF and ELF Communication Systems; SEEP update review presented at July 1978 meeting of committee held at Naval Research Lab. Category 1 rating revalidated.

2. Joint Department of Defense Space Experiments Review Committee, November 1977, held at Institute for Defense Analysis, Washington, D.C. Review of objectives, importance and relevance of SEEP experiment to DoD needs by joint USAF, US. Navy, US Army and NASA Board. SEEP experiment rated Category 1.

3. Defense Nuclear Agency -- Sept. 1978, SEEP Program reviewed with D. Evelyn, Atmospheric Effects Branch; April 1979 SEEP Program Update Review with MAJ. R. Bigoni, Chief, Atmospheric Effects Branch.

4. Defense Advance Research Projects Agency--SEEP Program reviewed with LT. COL. George Bulin, Nuclear Monitoring Office; Update Review held 9 April 1979 at DARPA, Washington, D.C..

5. Naval Ocean Systems Canter -- SEEP Program presented to DR. Ilan Rothmuller, April 1977 and Cooperative Program agreed to; reviewed for DR. Jurgen Richter, August 1977 and July 1978 at Navy Space Experiments Review; Update Review for DR. Richter and W. Moler in April 1979.

6. Assistant Secretary of the Navy for Research, Engineering and Science (ASN-R,E&S)--SEEP Program presented to DR. Thomas Quinn April 1979.

7. NASA Headquarters--SEEP Program reviewed with DR. David Cauffman, Solar Terrestrial Program Office in July 1978; Update Review presented to DR. Erwin Schmerling, Chief Solar Terrestrial Program Office on 9 April 1979.

8. NAVELEXSYSCOM--SEEP Program reviewed with DR. Gunter Brunhart of PME-117 in April 1979.

9. AFGL-SEEP Program coordinated with AFGL and CRL-242 experiment in April 1979.

58. EXPERIMENTER	
NAME DR. JOSEPH B. REAGAN	GRADE
ACTIVITY LOCKHEED PALO ALTO RESEARCH LABORATORY	TELEPHONE NO. 408-742-2870
DATE 6 APRIL 1979	SIGNATURE J B Reagan

59. PROJECT OFFICE	
NAME HOWARD A. POST	GRADE LCDR
ACTIVITY NAVY SPACE SYSTEMS ACTIVITY	TELEPHONE NO. 213-648-1648
DATE 2 May 1979	SIGNATURE H. A. Post

60. INTERMEDIATE ACTIVITY	
NAME R. G. JOINER	GRADE GS-15
ACTIVITY OFFICE OF NAVAL RESEARCH	TELEPHONE NO. (202) 696-4203
DATE 11 April 1979	SIGNATURE R. Gracen Joiner

61. SPONSORING ACTIVITY	
NAME GROVER M. YOWELL	GRADE RADM (U.S. Navy)
ACTIVITY Naval Electronic Systems Command PME 106	TELEPHONE NO. (202) 692-2182
DATE 14 June 1979	SIGNATURE Grover M Yowell

62. AGENCY STAFF APPROVAL	
NAME	GRADE
ACTIVITY	TELEPHONE NO.
DATE	SIGNATURE

63. ACCEPTANCE FOR SPACEFLIGHT	
NAME	GRADE
ACTIVITY	TELEPHONE NO.
DATE	SIGNATURE